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THE NARROWS SIPHON FROM BROOKLYN TO STATEN ISLAND[1]

By John P. Hogan[2]

The Narrows siphon built by the Board of Water Supply of New York City is a 36-inch flexible-joint cast-iron pipe line laid across the entrance to New York Bay from Brooklyn to Staten Island. The minimum depth, except at the approaches, is 60 feet below mean low water, and the maximum depth at the center of the channel is 74 feet. A pressure tunnel to convey the water from Brooklyn to Staten Island was rejected on account of the great cost of construction in comparison with the small amount of water to be delivered, the difficulty of determining all the conditions of the work with the rock at great depths, and the long time necessary to drive such a tunnel even under favorable conditions. A shield-driven tunnel was estimated to cost much more than a pipe line with flexible joints, and the latter was accordingly selected.

The siphon crosses the Narrows, as the entrance to the Bay is called, at a section where the shipping in and out of the Bay is very active, and where there are two anchorage grounds, one for merchant vessels and one for war ships. The government regulations prohibited refilling the pipe trench above an elevation 45 feet below mean low water. The pipe line had to be protected by at least 8 feet of backfill, which made it necessary to place the bottom of the pipe at least 56 feet below mean low water. This great depth rendered work on the bottom so difficult that it was considered preferable to lay the pipe in a continuous line by means of a cradle rather than to make up several lengths at the surface and joint these sections together after they were lowered to the bottom.

The angle of deflection of the joints in laying by means of a cradle was about 5 degrees, enough to destroy the effect of any ordinary calking of the lead in the joints, since the effect of this calking rarely extends farther than about $\frac{3}{4}$ inch into the lead, while the maximum movement of the spigot inside the hub was about 2 inches. If the calking were done in the usual way before the pipe began its movement down the cradle, the effect of the bending of the joint would be to loosen the lead so that after the pipe reached its final position on the bottom it would be necessary to calk the joint again. To do this in such a depth of water would be very difficult. Frequently flexible joint lines which leak very much at low pressures are relatively tight at high pressures, because the tightness of such a joint after flexing is due to the greater resistance of the bell than the spigot to the working pressure.

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[2] With Parsons, Klapp, Brinckerhoff & Douglas, 60 Wall Street, New York.

Experiments were accordingly made to ascertain if it was possible to design a joint which would permit the necessary motion and yet remain tight. It was not possible to find any material which did not shrink in cooling and thus make calkng necessary. Joints calked with lead wool proved tight but were not flexible. It was finally decided to pour the joints in the usual way and then attempt to calk them by forcing in lead pellets under great pressure to compensate for the shrinkage of the lead joint in cooling, estimated at about 10 per cent.

The first experiment was made as indicated in the sketch of Joint 1 in figure 1. Sixteen holes were bored through the bell at equal intervals and then tapped to receive a chrome steel gib screw. The joint was poured with lead in the usual manner. A mixture of flake graphite and anti-friction compound was placed in the holes and forced down by screwing the gib screws. The holes were next filled with cylinders of lead $\frac{1}{2}$ inch in diameter and 1 inch long and the screws again driven down, using a Little David air drill to rotate them. About seven of these little cylinders were used in each hole, after which it was closed by a cast-iron plug. The joint made in this way proved tight after being flexed and it was accordingly decided that it would be practicable to lay the pipe in the manner proposed.

Experiments were next undertaken to find the type of joint of this general pattern which would offer the greatest resistance to longitudinal pull. An ordinary pipe line becomes tight when subjected to a longitudinal strain but the joints will leak when the strain is released. In laying some short subaqueous pipe lines with flexible joints, they have been pulled considerably in laying and the weight or sag of the pipe has been relied upon to keep the line tight.

The Narrows siphon is so long that no reliance could be placed on the sag to keep the joints tight and it was also necessary to provide for temperature stresses. In the first experiment it was found that the lead in the bell did not flow, but was merely displaced by the pellets forced in, giving merely a band of tightness and not a satisfactory contact over the whole face of the bell.

The next experiment to ascertain if it was possible to increase the longitudinal strength of the joint was made with the holes moved forward to the position shown in Joint 2, figure 1. This was done to concentrate the lead at the greatest diameter of the bell, but it was unsuccessful because the lead was squeezed from the face of the joint.

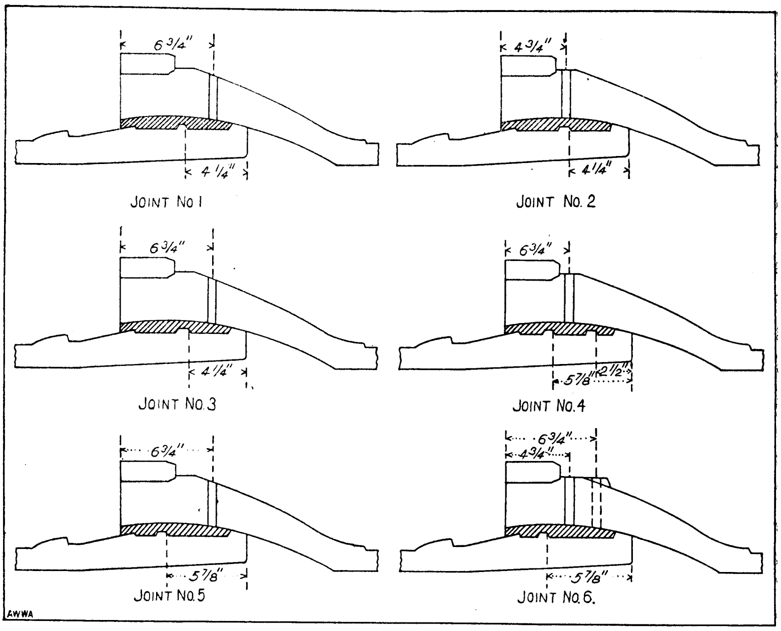

FIG. 1. EXPERIMENTAL FLEXIBLE JOINTS

Joint 3, similar to joint 1, was next tested. The only difference between the two was that in the latter experiment a much larger quantity of lead was forced into the holes. This did not give the desired results. After a certain amount of lead had been forced in, the introduction of any more drove the spigot out faster than it filled the space in the joint.

Joint 4 was then tried, and was found to have considerable longitudinal strength, but this was unfortunately gained at the expense of flexibility.

Joint 5 was designed to overcome the difficulty just mentioned. It proved on test to have good longitudinal strength and flexibility, but there was a slight leakage between the spigot and lead

Joint 6 was found to overcome all these difficulties, the two sets of gib-screwholes permitting the joint to be thoroughly calked without interfering with either flexibility or longitudinal strength. The details of the joint as finally worked out are shown in figure 2 There were two rows of screw holes, each row having 16 holes; the holes in the two rows were staggered.

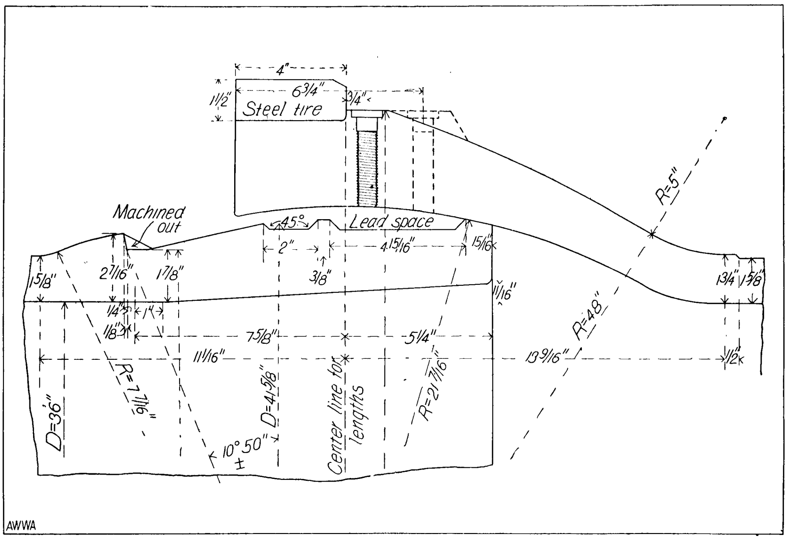

FIG. 2. FLEXIBLE JOINT USED ON NARROWS SIPHON

The joint was made on the deck of a scow as shown in figure 3. The inside of the bell was first coated with graphite. After the spigot of the next length of pipe had been centered in place, the lead was poured into the joint, about 280 pounds being used. Three cylinders of lead, each $\frac{9}{16}$ inch in diameter and $\frac{3}{4}$ inch long, were forced by compressed air into each of the back holes and one into each of the front holes. Grease to which 10 per cent of graphite had been added was forced into each hole and the gib screws driven down. About 24 pounds of pellets were used in a joint. The joint

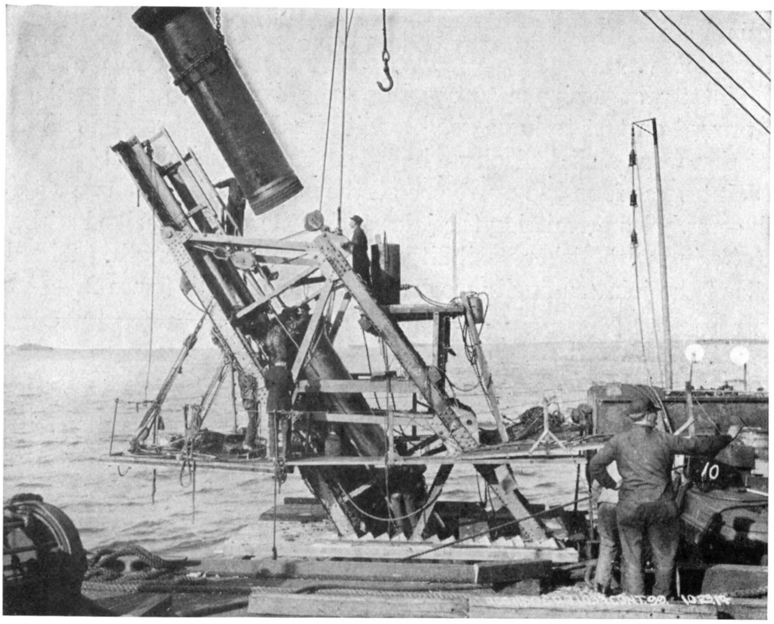

Fig. 3. Making Up a Joint

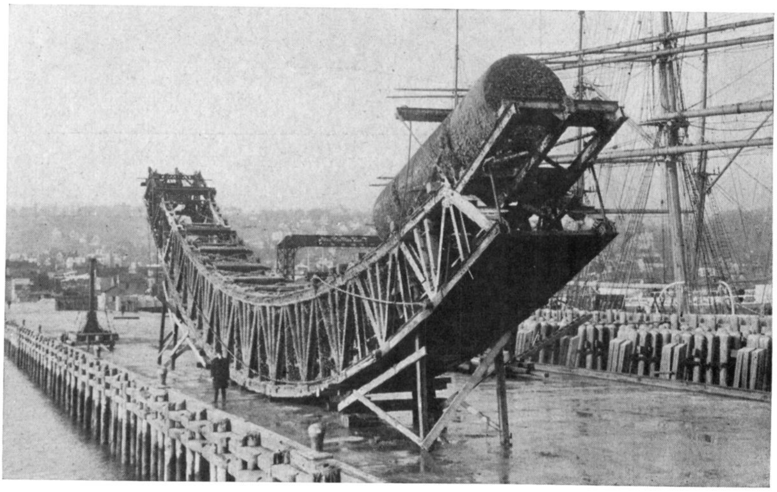

Fig. 4. Cradle with Float at Lower End

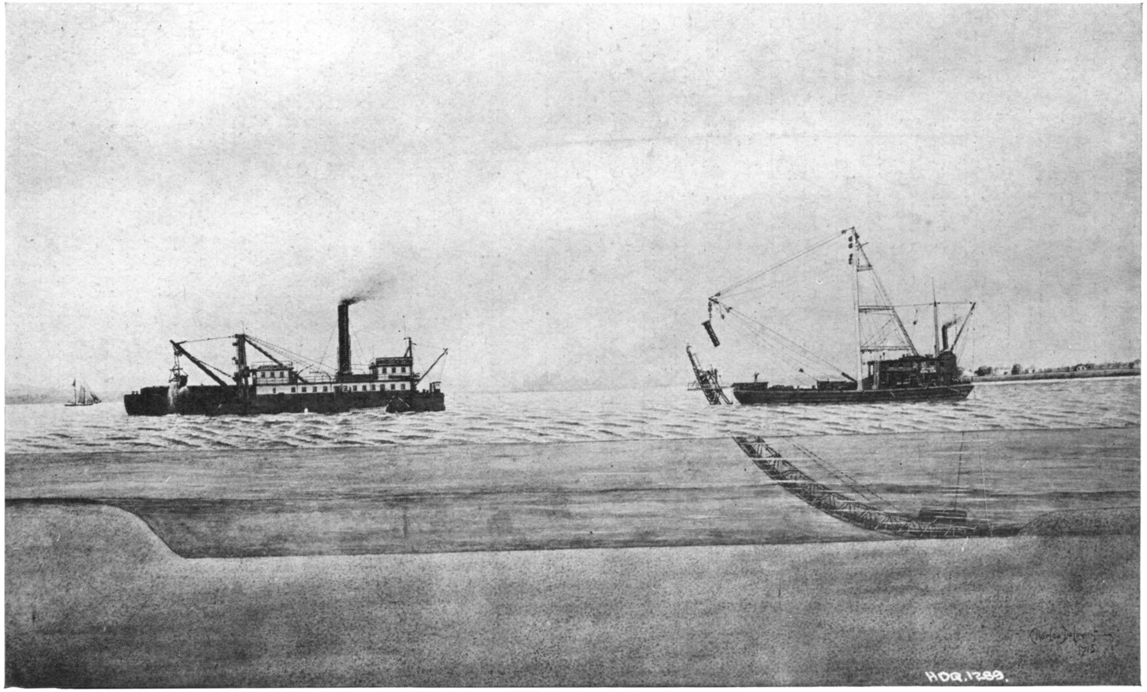

FIG. 5. DREDGING TRENCH AND LAYING PIPE FOR THE NARROWS SIPHON

was then deflected 5 degrees and tested under a hydraulic pressure of 100 pounds per square inch before it was launched.

The pipe-laying scow was 40 by 125 feet with a 70-ton derrick. It was held in position by ten anchors. Originally the cradle was swung from this derrick over the side of the scow, but later it was carried by cables running over a trunnion at one end. The cradle was built of structural steel, as shown in figure 4. It was 168 feet long, 8 feet wide and 10 feet high, and weighed nearly 60 tons.

The pipe was so tight when laid that no satisfactory measurement of the leakage could be obtained. The only trouble experienced was in the early stages, when the pipe was tested under a pressure of 120 pounds to the square inch with one end free in the cradle. One of the joints just beyond the end of the cradle buckled and was straightened and replaced by a harness and recalked with lead wool by divers.

In dredging the trench about 450,000 cubic yards of material were removed, the maximum depth of trench being about 38 feet. In general the material, fine sand and silt, stood on slopes of 2 horizontal to 1 vertical, with a bottom width of 20 to 30 feet. The trench was smoothed before laying by towing up and down a V-shaped drag similar to a snow plow. The pipe was covered with from 8 to 10 feet of refill.

Soundings taken one year after completion indicated that the unfilled trench above the refill is moving upstream, but there is no scouring at the bottom into the cover refill. The trench did not seem to be filling up at that time.

The whole 10,000 feet of pipe line was laid in two working seasons. Figure 5 shows the manner in which the dredge was kept working ahead of derrick scow, and the trench was backfilled close to the end of the cradle. At the end of the first season's work the cradle was pulled out from under the pipe and at the beginning of the next season's work the cradle was launched so that the rear end came within about 2 feet of the pipe already in place on the bottom. The pipe was then made up and allowed to slide down the cradle until it entered the bell of the last length laid. This joint was drawn together by a harness and calked with lead wool by divers. The harness was left in place.